



**NOAA Technical Memorandum NMFS-NE-225**

# **Estimated Loggerhead and Unidentified Hard-shelled Turtle Interactions in Mid-Atlantic Gillnet Gear, 2007-2011**

**US DEPARTMENT OF COMMERCE  
National Oceanic and Atmospheric Administration  
National Marine Fisheries Service  
Northeast Fisheries Science Center  
Woods Hole, Massachusetts  
May 2013**



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# **Estimated Loggerhead and Unidentified Hard-shelled Turtle Interactions in Mid-Atlantic Gillnet Gear, 2007-2011**

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# ABSTRACT

The total number of interactions between loggerhead and hard-shelled (loggerheads plus unidentified hard-shelled) turtles and commercial gillnet gear in the Mid-Atlantic from 2007-2011 was estimated by using data collected by Northeast Fisheries Observer Program (NEFOP) observers and at-sea monitors (ASM). A generalized additive model (GAM) was used to estimate interaction rates (defined as the number of turtles per ton of fish landed), which were then applied to commercial Vessel Trip Report (VTR) data to estimate the total number of interactions. From 2007-2011, an annual average of 95 hard-shelled turtles (CV = 0.21, 95% CI over all years: 60-138) and 89 loggerheads (equivalent to 9 adults) were estimated to have interacted with gillnet gear. An estimated 52 annual loggerhead interactions (equivalent to 5 adults) were considered to result in mortality. Gillnet trips landing monkfish had the highest estimated number of loggerhead and hard-shelled turtle interactions during 2007-2011. Estimated rates and interactions have decreased relative to those from 1996-2006.

# INTRODUCTION

Interactions between turtles and commercial fishing gear are considered a threat to the recovery of several species of turtles, including loggerheads (*Caretta caretta*), greens (*Chelonia mydas*), Kemp's ridleys (*Lepidochelys kempii*), and leatherbacks (*Dermochelys coriacea*). All of these species are protected under the US Endangered Species Act (ESA) of 1973, which aims to reduce or eliminate threats to the species to aid in their recovery. Here an "interaction" is defined as synonymous with the definition of a "take" under the ESA – i.e., to "harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect, or to attempt to engage in any such conduct" (ESA 1973).

Several hundred interactions between loggerheads and gillnet gear were estimated to occur each year during 1995-2006 (Murray 2009a). Historically, interaction rates between loggerheads and several types of commercial fishing gear have been higher in the southern Mid-Atlantic (i.e., waters off of Maryland to North Carolina) when surface water temperatures are warm (Murray and Orphanides 2013), and interactions with gillnets tend to be highest in large mesh nets ( $\geq 7$  in stretched mesh). Conservation measures have been implemented in the southern Mid-Atlantic to reduce the likelihood of commercial interactions with sea turtles. For instance, fishers are prohibited from using gillnets with mesh sizes  $\geq 7$  in during times and areas that overlap with the seasonal occurrence of loggerheads (US Department of Commerce 2002, 2006). Despite these conservation measures, fisheries observers continue to document interactions between sea turtles and gillnet gear in the Mid-Atlantic during times and areas outside of the large mesh closure restrictions or in mesh sizes smaller than 7 in.

This report describes characteristics of observed gillnet fisheries interactions with sea turtles from 2007-2011 and estimates the total number of loggerhead and hard-shelled turtle interactions, adult equivalent (AE) loggerhead interactions, and the number of mortalities from the interactions during this time frame. The estimate of hard-shelled turtle interactions include loggerheads plus unidentified hard-shelled species (i.e., a non-leatherback turtle that was observed in a gillnet but was not able to be identified to species). Adult equivalence considers a turtle's reproductive value (RV), defined as the contribution of an individual in an age-class to current and future reproduction (Fisher 1930), and is an important metric for understanding population-level impacts of fisheries interactions (Haas 2010). Total interactions are reported for

the entire gear type and also are apportioned by managed fish species landed (Murray 2009b) to aid in ESA Section 7 evaluations of management actions targeting specific fisheries.

## **METHODS**

### **Overview of Analysis**

Data collected year-round by Northeast Fisheries Observer Program (NEFOP) observers and at-sea monitors (ASM) aboard commercial gillnet vessels from 2000-2011 were pooled to model interaction rates of loggerhead and hard-shelled turtles. It was necessary to pool before 2007 to have a sufficient level of observed interactions to derive model-based estimates. Total interactions between leatherbacks and gillnet gear were not estimated because the low number of observations did not support a robust modeling approach, even with the larger pooled dataset. Moreover, estimates for Kemp's ridley and green turtles are not provided because interactions with these species occurred exclusively within internal North Carolina waters, and bycatch estimates for these species in this area are reported by the North Carolina Division of Marine Fisheries (NCDMF 2013).

Predicted rates were applied only to 2007-2011 commercial Vessel Trip Report (VTR) data because estimates of loggerhead rates and interactions from 1995-2006 are reported in Murray (2009a). Observer data prior to 2000 were not used to model rates because several new Fishery Management Plans (FMPs) were implemented that year, as well as an initial rule-making for large mesh closures (US Department of Commerce 2000), which significantly altered the magnitude and characteristics of current (2007-2011) fishing effort.

### **Study Region**

The northern extent of the study region was defined by the boundaries of the Mid-Atlantic Ecological Production Unit (EPU), characterized by distinct patterns in oceanographic properties, fish distributions, and primary production (Ecosystems Assessment Report 2012). The study region extended eastward from the continental coastline (including bays and internal North Carolina waters) to the Exclusive Economic Zone (EEZ) and southward to the southern extent of NEFOP data collection (~34°N) (Figure 1a).

### **Data Sources**

#### ***NEFOP and ASM observer effort***

A total of 2,658 trips (12,787 hauls) were observed by NEFOP observers from 2007-2011 in Mid-Atlantic region gillnet fisheries (Table 1, Figure 1a). Gillnets were either anchored to the bottom (65% of hauls), unanchored but fishing on the ocean bottom (32% of hauls), or drift/floating (3% of hauls).

Almost all NEFOP trips (96%) were considered “standard” observer trips, where observers are on board commercial vessels recording information about kept and discarded catch, fishing practices, and protected species interactions. An alternative platform observer program was employed from 2007-2009 because of the prevalence of gillnet fisheries prosecuted from small vessels (<7.3 m) that cannot easily accommodate observers (Kolkmeier et al. 2009). This program used a separate vessel, with a NEFOP-certified fisheries observer on board, that approached fishing vessels on the water to conduct observations. Roughly 4% of NEFOP trips

used in this analysis were collected via the alternative platform program in coastal areas of the southern Mid-Atlantic.

The ASM program began 1 May 2010 in response to Amendment 16 of the Northeast (NE) Multispecies Fishery Management Plan<sup>1</sup>. At-sea monitors are deployed on vessels that have been issued a limited access NE multispecies permit fishing under NE multispecies days-at-sea (DAS) (including monkfish (*Lophius americanus*), skate (*Leucoraja* and *Raja* spp.), and spiny dogfish (*Squalus acanthias*) trips that used a groundfish DAS). At-sea monitors collect data on catch, area fished, and protected species interactions. However, at-sea monitors collect less information than NEFOP observers do on fishing activity (such as depth and sea surface temperature[SST] at the fishing location), and they do not collect biological samples from protected species. In this analysis, a total of 209 trips (1,085 hauls) observed by at-sea monitors from May 2010 – December 2011 were pooled with the NEFOP data. As most of the ASM trips occur in the Gulf of Maine, only a small portion (9%) of ASM data was used in this analysis, and all trips were north of 39.5°N (Table 1, Figure 1b).

### Commercial Data

The primary data used in estimating total bycatch were VTR data because most VTRs contained the necessary information on fishing location and characteristics (e.g., mesh size) to derive total bycatch in this analysis. However, not all gillnet trips are recorded in the VTR database. A comparison of VTR landings with the Northeast regional (NER) dealer and North Carolina Department of Marine Fisheries (NCDMF) landings from the same state and federal waters revealed that about 30% of the commercial gillnet landings were not reflected in the VTR database. Therefore, VTR landings were adjusted upwards to equal the landings reported in the NER dealer database for all states except North Carolina, where landings were adjusted upwards based on the NCDMF data.

To adjust VTR data to match the magnitude of landings in the fishery landings databases (either the NER dealer or NCDMF data, depending on location), the VTR and fishery landings were first totaled by state and year strata (i). Next, an adjustment factor (AF) for each stratum was calculated as:

$$AF_i = \frac{\sum \text{Dealer landings}_i}{\sum \text{VTR landings}_i} \quad (1)$$

where i = year and state in which catch was landed. For each VTR trip in stratum i, the landed catch was multiplied by the AF for stratum i. These VTR data were considered to be an adequate representation of total fishing effort, based on previous explorations of the representativeness of VTR data (Murray 2009a).

Trips from Delaware and Maryland had the highest adjustment factors (AF > 25 in 2007 and 2009), though these trips accounted for only 0.2% of total gillnet fishing effort in the Mid-Atlantic. Excluding these outliers, adjustment factors ranged between 1-7.8 (median AF = 1.2).

### Sea Surface Temperature (SST) data

At-sea monitors and VTR logbooks do not record SST on their fishing trips. Instead, SST data were obtained from satellite sources, which varied depending on the year. For VTR trips

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<sup>1</sup> NOAA Fisheries 2011, 15 CFR Part 902, 50 CFR Part 648

during 2007-2009, SST data were obtained from either 5 day composites derived from Advanced Very High Resolution Radiometer (AVHRR) Pathfinder Version 52, Moderate Resolution Imaging Spectoradiometer (Modis) Aqua, Modis Terra, or Geostationary Operational Environmental Satellite (GOES) satellites, or 5 day climatology images downloaded from NASA's Jet Propulsion Laboratory, following methods in Murray (2009a). For VTR trips operating in North Carolina, where satellite-derived SST is biased warm (Murray 2009a), SST was predicted from observer-recorded temperatures based on statistical area and month ( $R^2=0.88$ ).

For 2010 and 2011, SST data were obtained from either a global high resolution Global 1km Sea Surface Temperature (G1SST) data source (Chao et al. 2009) or a multi-scale ultra-high resolution (MUR) data source (both downloaded from NASA's Jet Propulsion Laboratory) because the same SST sources used for 2007-2009 were not available. The sources used for 2010 and 2011 blend SST data from multiple sensors. These were the only sources used for at-sea monitor trips, which began in 2010. The preferred satellite source in the Mid-Atlantic was chosen depending on calendar quarter (MUR for April-June, and the G1SST for July-Dec), based on a comparison between satellite values and observer-recorded values at the same location. The relationships between the G1SST or MUR sources and observer-recorded SST were weak ( $R^2<0.30$ ) in January, February, and March, so for these months SST was predicted from observer-recorded temperatures based on statistical area and month ( $R^2=0.88$ ).

## Sea Turtle Interaction Rate Models

The interaction rate ( $R$ ) on each haul was defined as:

$$R = \frac{\text{Number of observed turtles}}{\text{Ton of fish landed}} \quad (2)$$

A Generalized Additive Model (GAM) with a Poisson distribution (GAM function, S-PLUS 7.0) was used to create two models: one model of the expected loggerhead interaction rate and the other of the expected hard-shelled turtle (loggerhead plus unidentified hard-shelled turtle) interaction rate. The form of the GAM can be written as:

$$\text{Log}(E[y_j]) = \log(\text{tons landed}_j) + \alpha + \sum_{i=1}^n f_i(x_{ij}) + \xi \quad (3)$$

where

- $y_j$  = the number of turtles observed on the  $j$ th haul
- $\log(\text{tons landed}_j)$  is an offset term for the unit of effort (tons landed) on the  $j$ th haul
- $\alpha$  = a constant intercept term
- $f_i$  = a series of smoothing splines for each predictor variable
- $x_{ij}$  = environmental or gear characteristics at the beginning of each haul
- $\xi$  = unexplained error

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<sup>2</sup> Reference to any specific commercial products, process, or service by trade name, trademark, manufacturer, or otherwise, does not constitute or imply its endorsement, recommendation, or favoring by the United States Government.



Loggerhead interaction rates with gillnet gear in the Mid-Atlantic have previously been modeled as a function of SST, mesh size, and latitude, and rates did not differ significantly each year during 1995-2006 (Murray 2009a). Therefore, a model describing interaction rates as a function of SST, mesh size, and latitude was used as a baseline candidate model to estimate loggerhead interaction rates with 2000-2011 data. Several additional variables were also tested, the models were evaluated with respect to Akaike's Information Criterion (AIC), and the percent of additional deviance explained was compared to the baseline model. These additional variables included: data source (ASM vs. NEFOP), inside/outside internal North Carolina waters, year, soak duration, depth, and trip type. Data source was tested because the ASM data only reflect characteristics of vessels fishing under NE multispecies DAS, and those vessels may fish differently than other gillnet vessels sampled by NEFOP observers. Any differences between NEFOP and ASM trips (beyond differences in variables already tested, such as mesh, soak duration, and year) would be captured by this variable. Trip type refers to the observer's sampling priorities on the trip, which could have an effect on whether a turtle interaction is witnessed as the haul is brought on board. All of the candidate variables were chosen based on a priori knowledge that they may influence loggerhead interaction rates. Because AIC evaluations tend to favor complex models for large datasets (Maunder and Punt 2004), variables were retained only if they increased the percent deviance explained by >5% (Warden 2011a; Murray 2009a).

The final model was checked for overdispersion, measured by calculating the dispersion parameter ( $\Phi$ ) defined as:

$$\Phi = \frac{\sum (y_i - \hat{\mu}_i)^2 / \hat{\mu}_i}{\text{residual } df} \quad (4)$$

Finally, estimated hard-shelled interaction rates were modeled as a function of the same variables in the preferred loggerhead model by using loggerheads plus unidentified hard-shelled turtles as the response. A model with different covariates was not explored because loggerheads composed most of the response in the hard-shelled turtle model.

## Total Estimated Interactions/Mortality

The loggerhead and hard-shelled models were each applied to adjusted VTR landings data from 2007-2011 to derive both an estimated loggerhead and hard-shelled interaction rate for each VTR trip and an estimated number of loggerheads and hard-shelled turtles caught on each VTR trip. The total of annual estimated interactions was the sum of the predicted number of turtles captured over all trips in a year. Total loggerhead interactions were estimated from the loggerhead model, plus a portion of the estimated hard-shelled interactions that were over and above the amount estimated from the loggerhead model. This additional portion of "presumed" loggerheads was based on the observed loggerhead proportion (84%) that occurred outside internal North Carolina waters (where all the unidentified interactions occurred). The number of mortalities was estimated by applying the mortality rate for gillnet gear (58%, Upite et al. 2013) to the total estimated interactions. The mortality rate does not differentiate between turtle species or life stages.

Bootstrap resampling was used to derive coefficient of variations (CVs) and confidence intervals (CIs) around total model-estimated interactions. Bootstrap replicates were generated by first resampling hauls with replacement 1000 times from the original observer dataset and then

computing total interactions by applying each replicate to VTR data. The 95% CI for total estimated bycatch was computed from the upper 97.5% and lower 2.5% quartiles of the bootstrap replicates.

## Estimated Adult Equivalent Interactions

An adult equivalent loggerhead is the RV of the turtle scaled to adults, where the RV for adults is equal to 1 (Wallace et al. 2008). Adult equivalent loggerhead interactions from 2007-2011 were estimated based on the methods in Murray (2011). Observed loggerheads were grouped into size classes based on the 6 loggerhead life stages (TEWG 2009), and RVs were assigned to each respective stage class based on Wallace (2008). These stage classes (RV values) were as follows: Stage 1 (0.002); Stage II (0.008); Stage III (0.040); Stage IVa (0.124); Stage IVb (0.547); and Stage V (1.0). Because the life stages overlap (TEWG 2009), size classes were truncated at the intersection of each life stage to create discrete size classes; stage IV was subdivided into 2 stages because RVs vary widely in this stage (Murray 2011).

The number of estimated adult equivalent (AE) loggerhead interactions over all 6 life stages and all 5 years was calculated as:

$$AE = \sum_{j=1}^5 \sum_{i=1}^6 T_j * P_i * RV_i \quad (5)$$

where T = total estimated loggerhead interactions in gillnet gear in year  $j$ , plus the portion of total estimated hard-shelled interactions presumed to be loggerheads

P = the proportion of loggerheads observed in life stage  $i$

RV $_i$  = the reproductive value for life stage  $i$

Because of the limited number of measured loggerheads from 2000-2011, P was based on NEFOP data collected from 1995-2011 ( $n = 14$  measured loggerheads).

## Estimated Interactions by Managed Fish Species Landed

When multiple species are landed, the estimated loggerhead interactions per trip are allocated to a managed fish species based on the proportion (by weight) of the species landed on the trip (Warden 2011b; Murray 2009b). Total loggerhead and hard-shelled interactions for managed fish species  $j$  on trip  $i$  ( $T_{ji}$ ) are multiplied by the proportion of reported landings of species  $j$  caught on trip  $i$ :

$$T_{ji} = T_i * L_{ji}/L_i \quad (6)$$

where  $L_{ji}$  is the amount of tons landed of species  $j$  on trip  $i$ , and

$L_i$  is the amount of tons landed on trip  $i$ .

Total estimated loggerhead and hard-shelled interactions for species  $j$  over all gillnet trips (N) from 2007-2011 is then:

$$T_j = \sum_{i=1}^N T_{ji} \quad (7)$$

Bootstrap resampling was used to derive CVs and CIs around the estimated interactions by managed species landed. Bycatch rate replicates in each stratum were applied to each VTR trip in that stratum to derive the estimated interactions, which were then apportioned across the managed species landed on that trip. For each replicate, estimates for the managed species were summed over all VTR trips, and the 95% CI was then computed from the upper 97.5% and lower 2.5% quartiles of the distribution.

For each managed fish species, a portion of the estimated hard-shelled turtles was presumed to be loggerheads by using the same approach as that used for the gear-wide estimate.

## RESULTS

### Characteristics of Fisheries Interactions

NEFOP observers reported a total of 7 loggerheads, 5 Kemp's ridleys, 12 greens, 1 leatherback, and 3 unidentified hard-shell species in Mid-Atlantic gillnet gear from 2007-2011, Figure 1a). In addition, at-sea monitors reported a total of 6 loggerheads, 1 leatherback, and 1 unidentified hard-shelled species during May 2010-2011 in the Mid-Atlantic, as well as 1 loggerhead in the western Gulf of Maine (which was excluded from the model as it was outside the spatial extent of the analysis) (Figure 1b). Turtles that were not positively identified to species had fallen from the gear before the observer was able to examine the turtle closely or take a photograph.

#### *Temporal and Spatial Distribution*

With the exception of the loggerhead that was captured north of 42°N in August, hard-shelled turtles were observed south of 41.5°N in waters ranging from 4-141m deep. All of the green and Kemp's ridley interactions, and 5 (71%) of the loggerhead interactions, occurred inside the barrier islands of Core Sound off North Carolina during 2009 and were observed via the alternative platform observer program. Hard-shelled turtles were observed in June, July, and August with SST ranging from 16.1–28.7°C. Leatherbacks were observed around 41°N and 35°N, in waters 13 and 46 m deep. Both leatherbacks were observed in October.

#### *Fishing Method*

Loggerheads were captured in gillnet mesh sizes ranging from 5.5–12 in; soaking from 12-48 hours; and catching predominately monkfish ( $n = 5$ ), skates ( $n = 2$ ), southern flounder (*Paralichthys lethostigma*) ( $n = 4$ ), bluefish (*Pomatomus saltatrix*) ( $n = 1$ ), and sandbar shark (*Carcharhinus plumbeus*) ( $n = 1$ ). Greens and Kemp's ridleys were captured in gillnets with mesh sizes ranging from 5.5–5.75 in, soaking from 12-21 hours, and catching southern flounder. Unidentified hard-shelled species were captured in gillnets with mesh sizes that were 12 in, soaking 72-216 hours, and catching predominately monkfish ( $n = 2$ ) or skate ( $n = 2$ ). Leatherbacks were captured in gillnets with mesh sizes of 3.6 or 12 in, soaking 2 or 72 hours, and catching Spanish mackerel (*Scomberomorus maculatus*) or monkfish, respectively.

When recorded (in NEFOP hauls only), the hang ratio of nets with turtle bycatch was almost always 0.50 (with the exception of one observed loggerhead in a net with a hang ratio of

0.33). All nets catching monkfish and skates that had observed bycatch were using tie-downs. No acoustic deterrent devices were on any nets with observed turtle bycatch.

### ***Animal Condition and Entanglement Situation***

Observers recorded turtles captured alive with or without injuries (7 loggerheads, 7 greens, 4 Kemp's ridleys, 1 leatherback, and 2 unidentified hard-shelled turtles), dead (4 loggerhead, 4 greens, and 1 leatherback), or of unknown condition (3 loggerheads, 1 green, 1 Kemp's ridley, and 2 unidentified hard-shelled turtles). Turtles were mainly entangled by their head or flippers in the net mesh, free of the floatlines or lead lines.

### ***Turtle Sizes***

The length (curved carapace length [CCL] from notch to tip) and width (curved width measured at widest part of carapace) of NEFOP-observed turtles were as follows: loggerheads (n = 2) were 60.6 and 75.0cm CCL and 60.0 and 72.0cm wide; greens (n = 7) were 27.6-34.3 cm CCL and 23.6-33.7 wide; Kemp's ridleys (n = 2) were 28.0 and 29.6 cm CCL and 28.2 and 30 cm wide; leatherback and unidentified hard-shell species sizes were not measured. Many turtles could not be measured if they fell from the net before they could be brought on board. Size measurements are also not recorded by at-sea monitors.

For the purpose of computing AEs, which used observed loggerhead measurements from 1995-2011, loggerheads were Stage II (n = 7, or 50%), Stage III (n = 5, or 36%), and Stage IVb (n = 2, or 14%).

### **Sea Turtle Interaction Rate Model**

The baseline candidate model from Murray (2009a) was found to be the best-fitting model of loggerhead interaction rates in the Mid-Atlantic gillnet fishery from 2000-2011. Interaction rates were modeled as a function of latitude, SST, and mesh size (Table 2); cumulatively, these three variables explained 39% of the variation in observed interaction rates. Variables indicating observer data source; inside/outside internal North Carolina waters; year, soak duration, depth, and trip type were not included in the model as they each explained <5% additional deviance over that explained by the baseline model. Estimated dispersion value of the final model was 0.80, indicating that the model was not overdispersed.

Estimated bycatch rates increased with decreasing latitude, increasing SST, and increasing mesh sizes (Figure 2). Estimated rates in large mesh (>7 in) gear in warm (>15°C) waters of the southern Mid-Atlantic have generally declined relative to those during 1996-2006, while those in the northern Mid-Atlantic have stayed relatively the same (Figure 3).

### **Total Annual Estimated Interactions, Adult Equivalent Interactions, and Mortalities**

From 2007-2011, an annual average of 95 hard-shelled turtles (CV = 0.21, 95% CI = 60-138) were estimated to have interacted with gillnet gear, and an annual average of 89 loggerheads (equivalent to 9 adults) (Figure 4). Of these 89, 54 (CV = 0.26, 95% CI=29-82) were estimated from positively identified loggerheads, and another 35 were hard-shelled turtles presumed to be loggerheads. An estimated 52 annual loggerhead interactions (equivalent to 5 adults) were considered to result in mortality.

VTR trips landing monkfish had the highest estimated number of loggerhead and hard-shelled turtle interactions during 2007-2011 (Table 3).

## DISCUSSION

With 5 years of additional monitoring data, loggerhead interaction rates in Mid-Atlantic gillnet gear continue to be associated with latitude, sea surface temperature, and mesh size. High interaction rates are estimated in the southern Mid-Atlantic, in warm surface temperature water, and in large mesh nets, and these findings are consistent with those in Murray (2009a). Average estimated interaction rates in large (>7 in) mesh gear in warm, southern Mid-Atlantic waters have declined in the last 5 years relative to those from 1996-2006, as did the total commercial fishing effort. On the other hand, large mesh commercial effort increased in the northern Mid-Atlantic, particularly after 2010, though the impact to turtles was relatively small because estimated rates in that region are low. The reduction in commercial effort in the southern Mid-Atlantic, combined with lower estimated interaction rates, contributed to fewer estimated turtle interactions in the last 5 years. From 2007-2011, roughly 89 estimated loggerhead interactions occurred each year, compared to an annual average of 288 estimated interactions from 2002-2006 (Murray 2009b).

Expressing interactions in terms of adult equivalents allows managers to compare different fishing activities under a “common currency” of expected reproductive output (Wallace et al. 2008). A larger number of adult equivalent interactions implies a greater impact on the population. Other types of fishing gear interact with loggerheads in the Mid-Atlantic, such as bottom otter trawls and scallop dredges. Annual estimated adult equivalent loggerhead interactions are higher in trawl gear (Warden 2011a) than in scallop dredge (Murray 2011) or gillnet gear (this analysis) because of a larger magnitude of total interactions and a higher proportion of larger turtles taken in the fishery.

In this analysis, a portion of the estimated hard-shelled turtles were added to the model-based estimates of loggerheads because otherwise the model-based estimates would have only reflected a minimum estimate. The portion of estimated hard-shelled turtles presumed to be loggerheads was based on the observed proportion (84%) of loggerheads outside internal North Carolina waters, where all the unidentified interactions occurred. This presumed loggerhead portion was also applied to the estimated hard-shelled turtles for each managed fish species. While this portion may differ for each managed fish species depending on the spatial distribution of both the fish and turtle species, there were too few interactions, and little or no observer coverage in some fisheries, to tailor the “loggerhead portion” to each managed fish species.

Estimated turtle interactions are assigned to individual managed fish species to support ESA Section 7 consultations for various Fishery Management Plans (FMPs). The approach explicitly recognizes that gear and environmental factors affect interaction rates on individual fishing trips, rather than the fish species caught or targeted. While this approach is consistent with the interaction rate models, the estimates will reflect the composition of catch as reported in VTR data. If non-federally regulated fish species are sold, and the vessel does not possess a permit for a federally regulated species, a VTR logbook record is not required to be filed. If this or other factors result in some species being underrepresented in the VTR data, estimated takes will be underestimated in these fisheries, and possibly overestimated in other fisheries.

Landings data were used as the measure of fishing effort in this analysis because landings data are generally recorded and available for the entire fishery, and this unit of effort is

consistent with historic bycatch analyses of loggerheads in the Mid-Atlantic (Murray 2009a). An alternative unit of effort which reflected the amount of time and gear fished (expressed as soak time \* net length) could not be explored because of limitations in the VTR data. To evaluate the quality of effort information recorded on VTR trips, over 3,000 VTR logbooks from 2007-2011 were matched to logbooks recorded by observers for the same trip. On average, the quantity of gear recorded on VTR logbooks was three times larger than the information recorded by observers on the same trip. Applying estimated rates (modeled by using observer data) to inflated VTR effort would have overestimated the total number of loggerhead interactions. Therefore, a decision was made not to use soak time \* net length (which is calculated from the quantity of gear recorded on the log) as a unit of effort.

An alternative approach to estimate interactions was investigated to determine that the model-based estimates were robust. The alternative approach used stratified ratio estimators to estimate hard-shell species and loggerhead interactions by using observer and ASM data from only the more recent years, 2007-2011. In this approach data were stratified by time period (pre and post ASM monitoring), region (Mid-Atlantic vs. Gulf of Maine), season (summer [16 May – 31 Oct] vs. winter [1 Nov – 15 May]), and mesh size ( $>7$  in mesh vs.  $\leq 7$  in mesh). Observed loggerhead and hard-shelled turtle interaction rates (expressed as number of turtles per ton of fish landed) were computed in each stratum and applied to adjusted VTR data to derive total estimated interactions. The model-based estimates of both loggerhead and hard-shelled turtles reported here were within the 95% confidence intervals for those estimated with stratified ratio estimators, and the model-based estimates had lower CVs. Thus, pooling data from 2000-2011 does not appear to have biased estimated interaction rates from 2007-2011, and pooling led to more precise estimates.

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**Table 1. Annual Northeast Fisheries Observer Program (NEFOP) and at-sea monitors (ASM) observer effort and observed turtles in Mid-Atlantic gillnet fisheries from 2007-2011. AVTR=Adjusted Vessel Trip Report Landings; OC = Observer Coverage, expressed as: (NEFOP tons + ASM tons)/AVTR tons \* 100. Obs = observed, Cc = Loggerhead (*Caretta caretta*); Dc = Leatherback (*Dermochelys coriacea*); Cm = Green (*Chelonia mydas*); Lk = Kemp's ridley (*Lepidochelys kempii*); Unid = Unidentified hard-shelled turtles. Information prior to 2007 is reported in Murray (2009a).**

Year	NEFOP Trips	NEFOP Tons Landed	ASM Trips	ASM Tons Landed	AVTR Tons Landed	OC	Obs Cc	Obs Dc	Obs Cm	Obs Lk	Obs Unid
2007	814	756	0	0	20725	4%	0	1	0	0	0
2008	556	445	0	0	19375	2%	1	0	0	0	0
2009	455	423	0	0	21631	2%	6	0	12	5	2
2010	506	520	52	217	17044	4%	4	0	0	0	1
2011	327	349	157	390	24062	3%	2	1	0	0	1
Total	2658	2493	209	607	102839	3%	13	2	12	5	4

**Table 2. Variables examined in analysis of factors affecting estimated interaction rates of loggerhead turtles (*Caretta caretta*) in gillnet gear. df = degrees of freedom, AIC = Akaike's Information Criterion, k = number of parameters. The "baseline" model is shaded in gray and reflects the preferred model in Murray (2009a), as well as this analysis.**

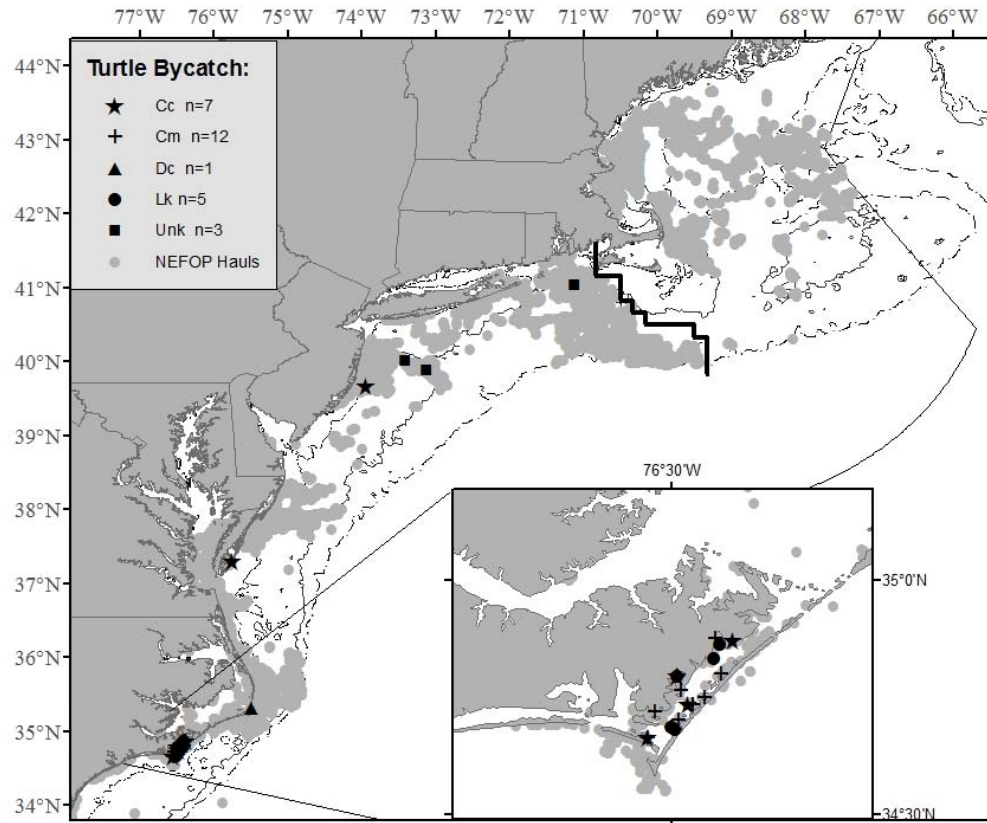
Model structure	Residual df	Residual deviance	Cumulative % of deviance explained	% deviance explained by additional variable	AIC	ΔAIC (relative to baseline model)	k
Null model	33209.0	428.9			430.9		1
Null + latitude + s(sst) + s(mesh)	33200.1	260.9	0.39		280.7	0	8
Null + latitude + s(sst) + s(mesh) + observer data source	33199.1	256.4	0.40	0.01	278.2	2.5	9
Null + latitude + s(sst) + s(mesh) + (in/out NC sounds)	33199.1	257.0	0.40	0.01	280.8	-0.1	9
Null + latitude + s(sst) + s(mesh) + s(year)	33196.2	254.2	0.41	0.01	281.8	-1.1	11
Null + latitude + s(sst) + s(mesh) + (year)	33189.1	241.9	0.44	0.04	278.2	2.5	19
Null + latitude + s(sst) + s(mesh) + s(soak duration)	33196.2	250.6	0.42	0.02	278.2	2.5	11
Null + latitude + s(sst) + s(mesh) + s(depth)	33196.2	254.9	0.41	0.01	282.5	-1.8	11
Null + latitude + s(sst) + s(mesh) + trip type	33198.1	260.8	0.39	0.0	284.6	-6.4	10

**Table 3. Annual and average estimates of loggerhead (*Caretta caretta*) and hard-shelled turtle interactions by managed species landed in Mid-Atlantic gillnet gear, 2007-2011. Estimated loggerheads include those estimated by the model, plus the portion of estimated hard-shelled turtles presumed to be loggerheads. Confidence intervals are around the mean estimates in each time period. Only those managed species with estimated turtle interactions are reported. ATOL = Average Tons Observed Landed, NEFOP = Northeast Fisheries Observer Program, ASM= at-sea monitors, CV = Coefficient of variation, CI = Confidence interval. Columns might not sum to reported totals because of rounding of numbers.**

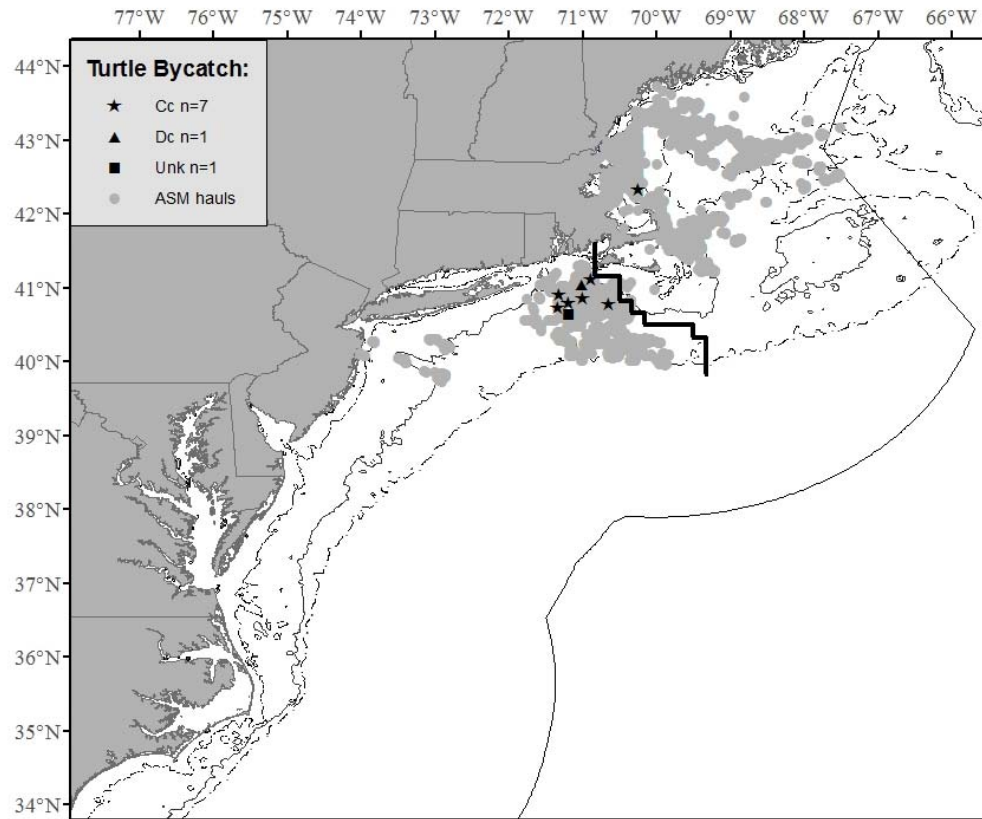
Managed Species <sup>3</sup>	ATOL (NEFOP and ASM)	Estimated Loggerheads								Non-Loggerhead Estimated Hard-Shelled Turtles							
		2007	2008	2009	2010	2011	Mean	CV	95% CI	2007	2008	2009	2010	2011	Mean	CV	95% CI
Monkfish	196	23	44	7	23	39	27	0.28	16-41	2	3	0	1	3	2	0.24	1-2
Skates	218	6	10	6	30	30	16	0.30	9-23	0	1	0	2	2	1	0.23	1-2
Spiny dogfish	43	2	2	4	7	11	5	0.37	2-8	0	0	0	1	1	0	0.29	0-1
Smooth dogfish	18	9	11	14	23	26	17	0.54	6-32	0	1	2	2	2	2	0.38	1-2
Bluefish	49	14	7	22	22	7	14	0.46	6-26	1	0	2	2	1	1	0.34	1-2
Summer flounder	2	0	0	0	0	1	0	0.38	0-0	0	0	0	0	0	0	0.30	0-0
Croaker	55	18	3	2	2	4	6	0.43	2-10	1	0	0	1	0	0	0.32	0-0
Spanish mackerel	5	0	0	1	1	1	1	0.73	0-1	0	0	0	0	0	0	0.56	0-0
King mackerel	1	1	0	0	1	1	1	0.53	0-1	0	0	0	0	0	0	0.40	0-0
Sandbar shark	0	1	1	0	0	0	0	0.65	0-1	0	0	0	0	0	0	0.53	0-0
Black-tipped shark	0	1	2	0	1	0	1	0.41	0-1	0	0	0	0	0	0	0.31	0-0
Thresher shark	0	0	0	0	1	0	0	0.48	0-0	0	0	0	0	0	0	0.34	0-0
Sharpnose shark	0	0	1	0	1	0	0	0.43	0-1	0	0	0	0	0	0	0.32	0-0
Black drum	0	0	1	0	1	0	0	0.54	0-1	0	0	0	0	0	0	0.43	0-0
Total		75	82	55	113	120	89			4	5	4	9	9	6		

<sup>3</sup> Scientific names for the managed species are as follows: monkfish (*Lophius americanus*); skates (*Leucoraja* and *Raja* spp.); spiny dogfish (*Squalus acanthias*); smooth dogfish (*Mustelus canis*); bluefish (*Pomatomus saltatrix*); summer flounder (*Paralichthys dentatus*); croaker (*Micropogonias undulatus*); Spanish mackerel (*Scomberomorus maculatus*); King mackerel (*Scomberomorus cavella*); sandbar shark (*Carcharhinus plumbeus*); black-tipped shark (*Carcharhinus limbatus*); thresher shark (*Alopias vulpinus*); sharpnose shark (*Rhizoprionodon terraenovae*); black drum (*Pogonias cromis*)

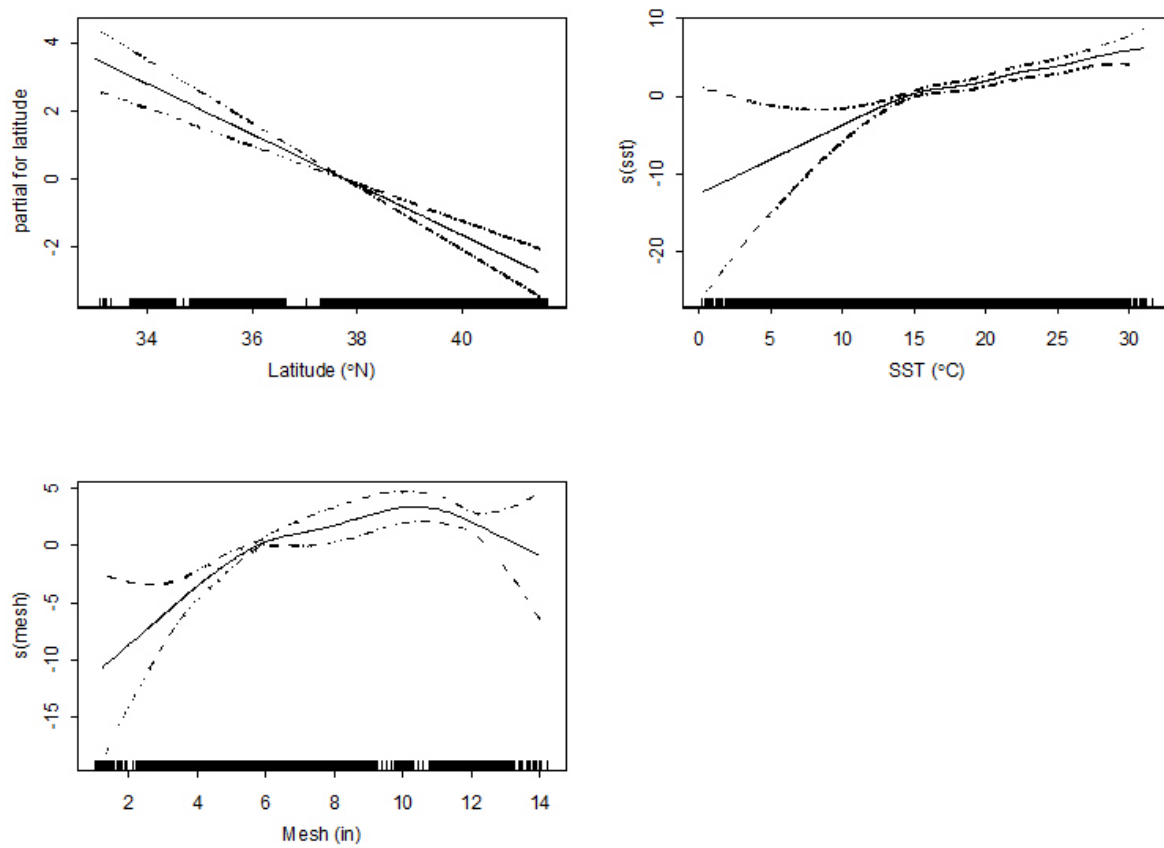
**Figure 1a. Northeast Fisheries Observer Program (NEFOP) observed gillnet hauls and turtle interactions, 2007-2011. This analysis encompasses the region south and west of the solid black line, depicting the boundary of the Mid-Atlantic Ecological Production Unit (Ecosystems Assessment Report 2012). Cc = Loggerhead (*Caretta caretta*), Cm = Green (*Chelonia mydas*), Dc = Leatherback (*Dermochelys coriacea*), Lk = Kemp's ridley (*Lepidochelys kempii*), and Unk=Unidentified hard-shelled species.**



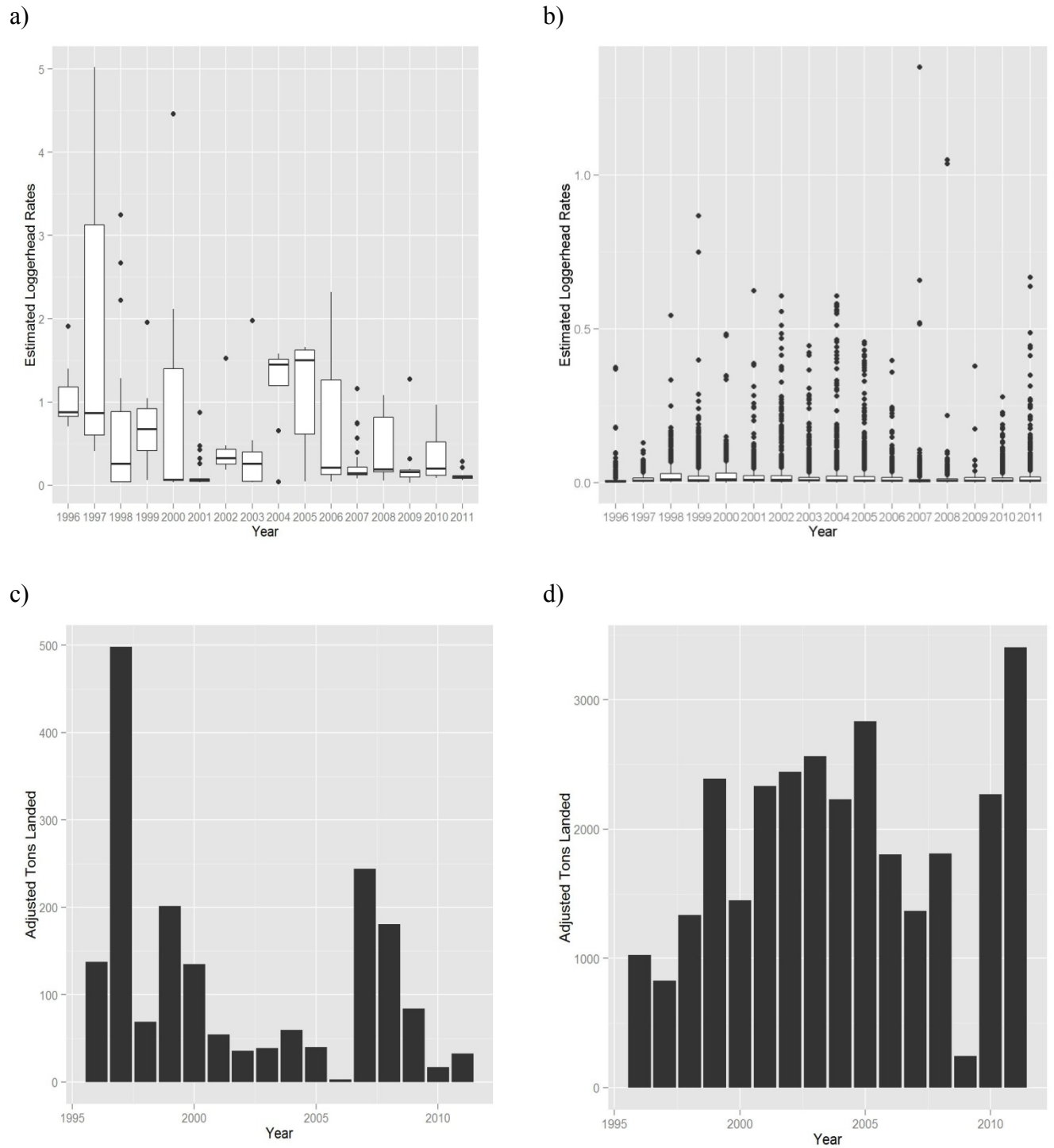
**Figure 1b. At-sea monitor (ASM) observed gillnet hauls and turtle interactions, May 2010-2011. Data from the region south and west of the solid black line were used in this analysis. Cc = Loggerhead (*Caretta caretta*), Dc = Leatherback (*Dermochelys coriacea*), and Unk=Unidentified hard-shelled species**



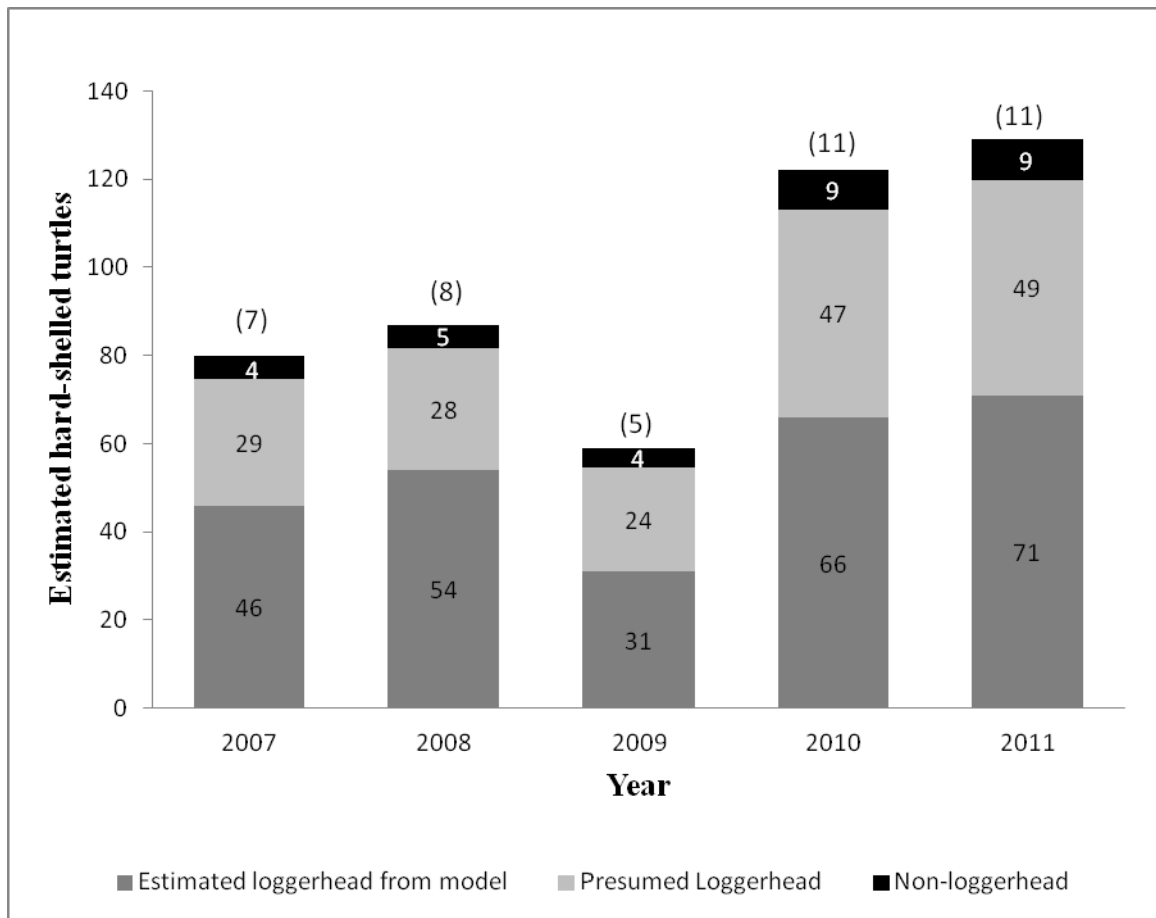
**Figure 2. Generalized additive model smoothers depicting partial effects of latitude, sea surface temperature (SST), and mesh size on loggerhead (*Caretta caretta*) interaction rates.**



**Figure 3. Estimated loggerhead (*Caretta caretta*) interaction rates (turtles per metric ton landed) and vessel trip report (VTR) tons landed from 1996-2011 on VTR trips fishing a, c) south of 37°N, in waters >15°C, with large (>7 in) gillnet mesh, and b, d) north of 37°N, in waters >15°C, with large (>7 in) gillnet mesh. Rates prior to 2007 are from Murray (2009a). Note the different y-axis scales.**



**Figure 4. Total estimated hard-shelled and loggerhead (*Caretta caretta*) turtle interactions in gillnet gear during 2007-2011, including adult equivalent loggerhead interactions in parens. Estimated loggerhead interactions include those estimated from the loggerhead model, plus a portion of estimated hard-shelled turtles presumed to be loggerheads.**





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